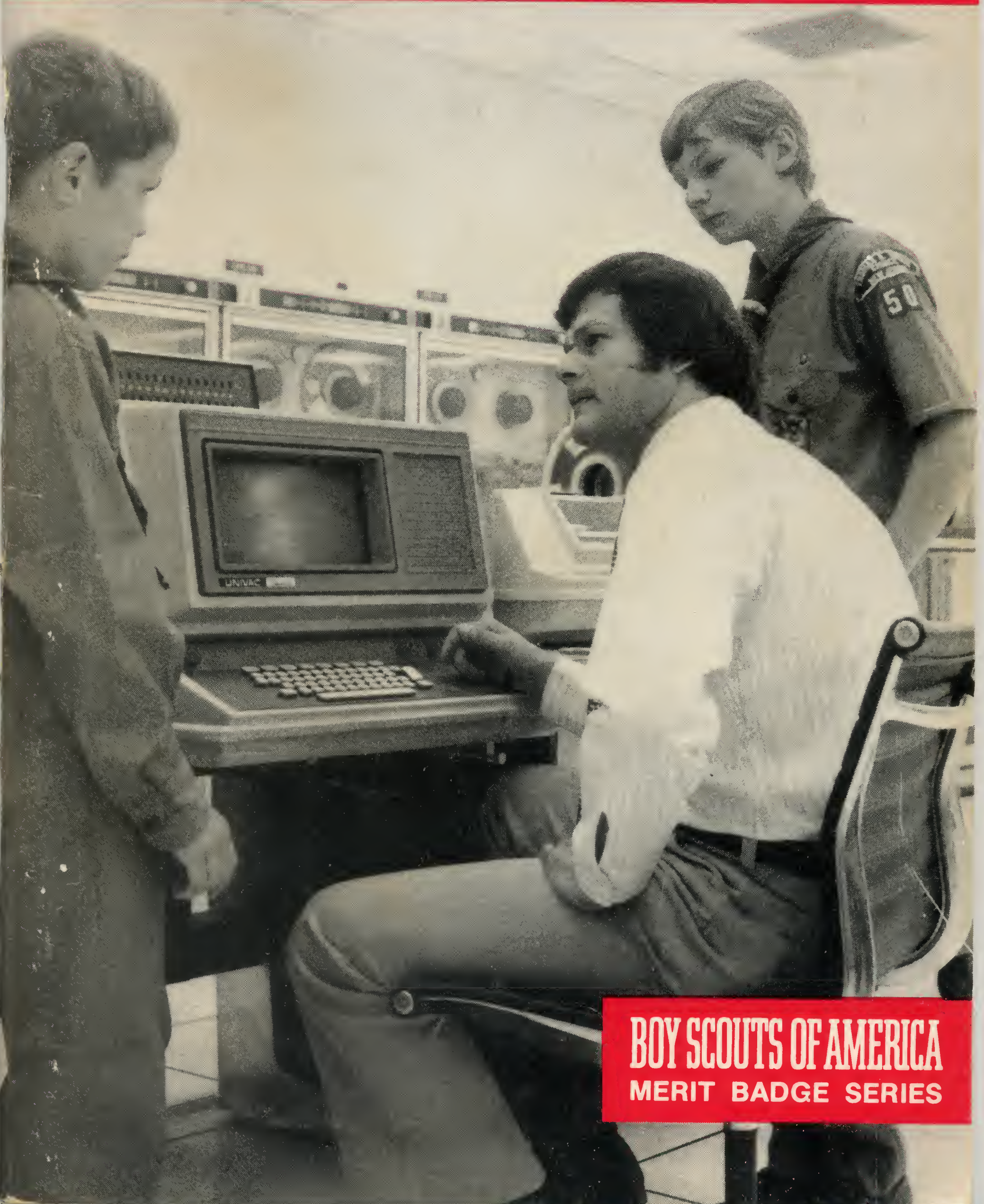
COMPUTERS



BOY SCOUTS OF AMERICA

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COMPUTERS

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Contents

Requirements

1. Do the following:
   a. Give a short history of computers. Describe the major parts of a computer system. Give four different uses of computers.
   b. Describe the differences between analog and digital computers. Tell the use of each.
   c. Explain some differences between special- and general-purpose machines.

2. Do the following:
   a. Tell what a program is and how it is developed.
   b. Explain the difference between an assembler and a compiler. Tell where each might be used. Describe a source and an object program.
   c. Use a flowchart diagram to show the steps needed to set up a camp.

3. Do one of the following:
   a. Prepare flowcharts to find out the average attendance and dues paid at the last five troop meetings.
   b. Prepare flowcharts to work out a simple arithmetic problem. Explain to your counselor how this program could be stored in a computer. Tell how it could be used again.

4. Do the following:
   a. Name four input/output devices for computers. Explain the use of two of them in a system.
   b. Explain the Hollerith code. Show how your name and address would be punched on a card.

5. Tell the meaning of six of the following:

a. memory
b. bits
c. on-line
d. bytes
e. microsecond
f. address
g. channel
h. interrupt
i. register
j. console
k. central processing unit

6. Tell the meaning and use of 12 of the following:

a. business data processing
b. information retrieval
c. simulation
d. scientific processing
e. floating point
f. truncation
g. fixed point
h. accuracy
i. input
j. record
k. output
l. file
m. software
n. instruction
o. hardware
p. indexing
q. loop
r. subroutine
s. real time
t. time sharing
u. cybernetics

7. Visit a computer installation. Study how it works.

8. Do the following:

a. Explain what each of the following does:
design engineer
customer engineer
programmer
analyst
operator
salesman
b. Read two pieces of information about computers. Describe what you read.
c. Describe jobs in the computer field.

The Computer

1. Do the following:

- **a. Give a short history of computers. Describe the major parts of a computer system. Give four different uses of computers.**
- **b. Describe the differences between analog and digital computers. Tell the use of each.**
- **c. Explain some differences between special- and general-purpose machines.**

A complete history of the development of computers would make up a very large volume. The need to compute is as old as man himself and may even be older than mathematics. The real interest in studying for the Computers merit badge is to give you an understanding of how man developed ways to simplify his calculations. Although the original purpose of computers was to provide a means for the fast solution of numerical problems, today this has been expanded by computer scientists to provide for the solution of many problems totally unrelated to mathematics or even numbers.

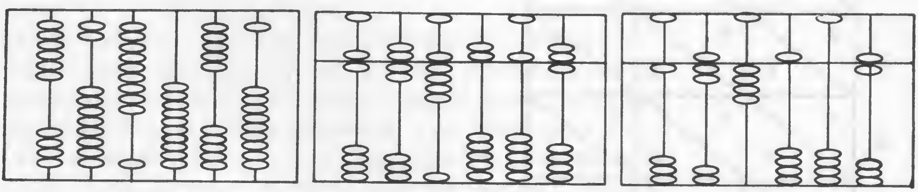
In considering the subject of this merit badge, we must carefully distinguish between a computer and a calculating machine. Not long ago, it was customary to apply the term "computer" to a person who operated a calculating machine. In this pamphlet we shall follow the definition of the word "computer" as given by the International Federation of Information Processing (IFIP) and American National Standard Institute (ANSI): *Computer: a data processor that can perform substantial computation, including numerous arithmetic or logic operations, without intervention by a human operator during the run.* In this description, it is assumed that a *data processor* is a machine capable of working with data and includes adding machines, slide rules, or even the abacus. A *run* is the sequence of operations which are necessary to find the solution to a problem. Hence, the feature which sets a *computer* apart from a calculating machine is the ability of the *computer* to perform without human control.

The computer today owes much to earlier inventions of calculating machines. Obviously, an ox and cart is not in the same class as an automobile, but an automobile is clearly a descendant of the ox and cart, and both vehicles depended on the invention of the wheel. In the same way, the computer and calculating machine depended on the inventions of mechanical methods of doing arithmetic.

The History of Computing

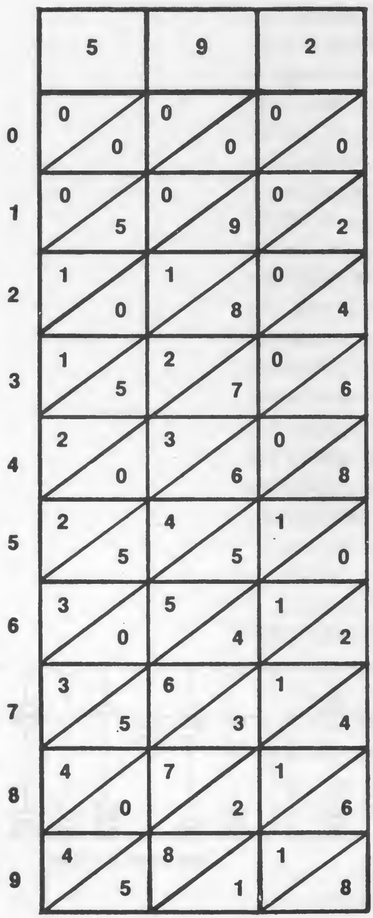
400 B.C. Far East.—The first true calculating machine was the *abacus,* which is still used in some countries. It was in use at least four centuries before Christ and exists in three basic designs — the Chinese, the Japanese, and the Russian versions. Each style of abacus consists of a set of beads strung on wires within a rectangular frame. Each wire of an abacus represents a single digit in a number. The position of the beads on each wire represents a particular digit. In the Russian version, each wire holds 10 beads, as shown in the figure. In the Japanese and Chinese versions each wire is divided into two *fields,* the upper part representing the number of fives and the lower part the remaining digits. In the Chinese version, the upper field contains two beads and the lower field contains five beads. In the Japanese version, the upper field contains one bead and the lower field contains four beads. With practice, it can be seen that the Japanese version is easier to use since there are fewer beads to move about and the number of beads in a group are easier to recognize by eye. A clever operator of an abacus can do arithmetic at amazing speed, easily going as fast as a mechanical adding machine.

Figures of abacuses showing the number 629051

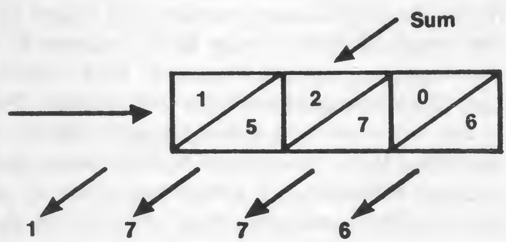


Russian Schoty — Chinese Saun-Pan — Japanese Soroban

1617 Scotland.—The problem of mechanizing the multiplication tables was solved by John Napier, who invented a set of rods (which became known as Napier's Bones since they were made out of ivory) on which were inscribed the multiplication tables. Napier recognized that the major problem in multiplication was to carry digits from one position to the next. His "bones" were so arranged that the units digit of one multiplication and the carry from the previous position were correctly seen. Although not really a mechanical device, Napier's invention led the way to later inventions of truly mechanical machines.



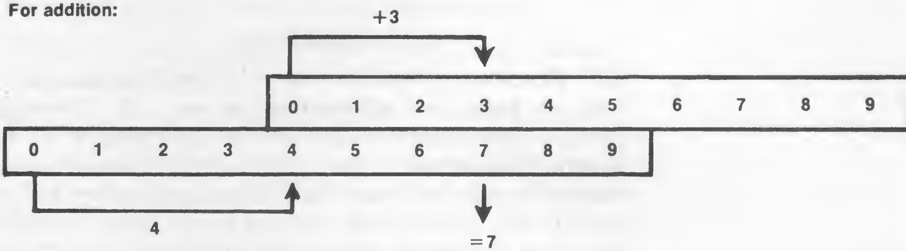
Napier's Bones. To Multiply 592 by 3, choose the set of bones corresponding to 5, 9, and 2 and place them together in order. Read the result from the bones at the level corresponding to the multiplier 3, adding the pair of digits which appear in each diagonal "slot."



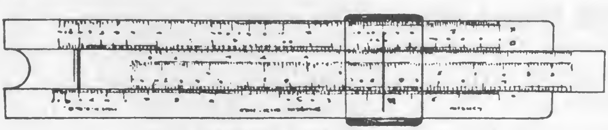
Napier also invented logarithms, which is a way to turn problems of multiplication and division into simple operations of addition and subtraction. The invention of logarithms led directly to the invention of the slide rule. A slide rule consists of two scales that can be moved against each other. For example, take two pieces of card marked off in equal intervals and numbered so that the scales match each other when the two cards are placed together. Addition can then be done by setting the zero position on the top scale opposite the first addend on the bottom scale. The result of the addition can be read on the bottom scale opposite the marker of the second addend on the top scale.

SLIDE RULES

For addition:

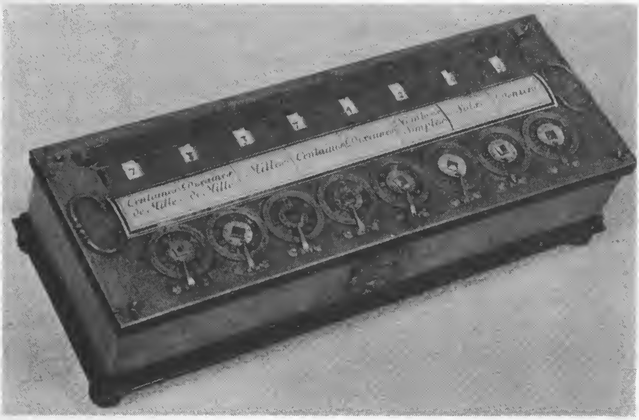


For multiplication:



1642 France.—The first real machine, an adding machine, was invented by the French philosopher and mathematician Blaise Pascal. It worked much the same as modern desk adding machines. The digits from 0 to 9 were engraved on wheels. The first wheel represented 0 to 9; the second, the tens digit; the third, the hundreds digit; etc. If the operator wanted to *store* (register) 136 in the machine, he would turn the third

wheel to 1, the second to 3, and the first to 6. If he wanted to add to this figure, he turned the first wheel five places. Through a series of gears, this action turned the second wheel from 3 to 4, for a new total of 141.



Pascal's calculator

1801 France.—A weaver named Joseph M. Jacquard had an idea for automating a loom by using a punched board, the basis for the first modern computers. Making patterns in cloth was very costly, and Jacquard got the idea of guiding the needles by allowing only the ones he wanted to use to go through the holes in the board. Very intricate patterns could be made cheaply by this early automated loom. The same principle was used in many early computers.

1889 United States.—Dr. Herman Hollerith, a statistician from Buffalo, N.Y., developed the Hollerith punched card and card machine, which was the first electrically driven computer. It was first used in the census of 1890. The method was to float each of the coded punched cards with the data about one American across a pool of mercury. Telescopic pins overhead dropped through the holes. When a pin touched the mercury, it made an electrical contact, and one more fact about an American was recorded. To exploit his invention Hollerith formed a company which, after a merger, became International Business Machines Corp. (IBM).

1946 United States.—The first truly electronic computer was built at the University of Pennsylvania by

Dr. J. Presper Eckert and Dr. J. Mauchly. The machine was named ENIAC (**E**lectronic **N**umerial **I**ntegrator **A**nd **C**omputer) and contained 18,000 vacuum tubes. There were stories that whenever ENIAC was turned on all the lights in a suburb of Philadelphia would dim! Parts of the ENIAC computer can be seen at the Smithsonian Institution.

During the period of the development of the ENIAC, Dr. John von Neumann of Princeton proposed a scheme for the control of computers by which the directions (called *instructions*) to solve a problem were to be stored in the computer. This idea became known as the *stored program concept*, and the computers that were designed on this basis are known as *stored program computers*. With this idea, the computer was truly invented.

1950 United States.—The first stored program computer built in the United States was the EDVAC (**E**lectronic **D**iscrete **V**ariable **A**utomatic **C**omputer), also built at the University of Pennsylvania.

Other Developments of the 1940's and 1950's.—Although there has been little change in the basic ideas of the manufacturer of a computer since the EDVAC, the invention of transistors by Bell Telephone Laboratories has greatly increased the speed of computation and has lowered the cost of production.

Minicomputers exist today that are not much larger than a breadbox, and there are computers that fill large rooms and perform extremely complex tasks that could not have been possible a few years ago. The advent of the microcomputer in the mid 1970's has led to the use of computers in many everyday devices, including the telephone and television.

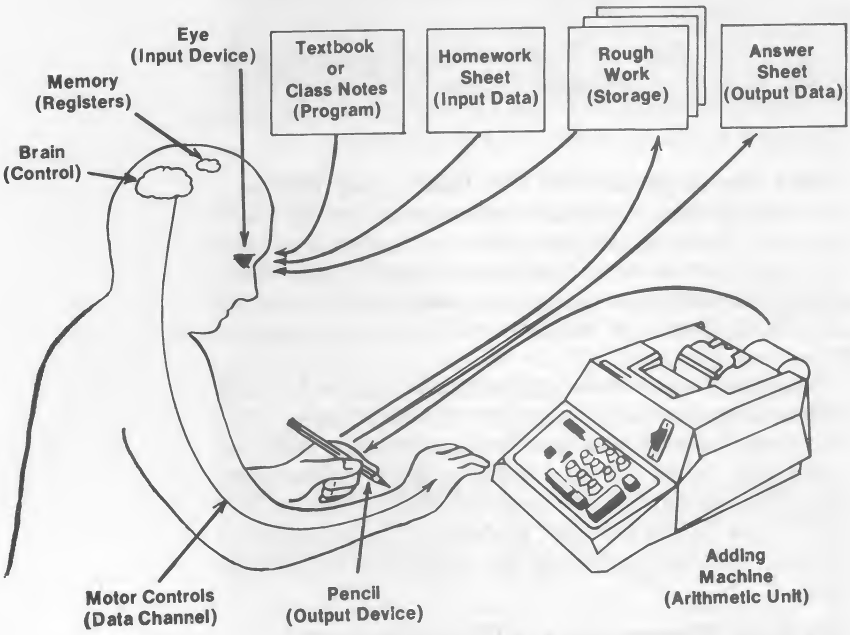
The Major Components of a Digital Computer

Let us develop the components of a digital computer from the basis of you performing a homework problem given in school and assuming that you have available to you a simple adding machine. We can assume that you have been given a set of instructions (directions) on how to solve the problem.

The basic process of problem solution is to look at the book or notes to find out how to solve the problem and through the use of eyes and the motor

controls of the arm and the hand convert those instructions into arithmetic operations, place the results on paper, and operate the adding machine. Each action on your part can be classified as a sequence: look with the eyes, interpret with the brain (using a portion of memory to "store" the information so that you don't have to keep looking at the same place), and direct an action. Actions may be classified as either finding the next instruction, performing a calculation (using the adding machine), or rewriting answers from one place to another.

This "setup" is essential for any kind of calculation, so let us now "automate" the process by replacing parts of the human system with electronic devices.



The eye acted as the input device to the human system, capable of collecting information from the outside world and passing it to the brain and the memory. We shall replace the eye by an input mechanism and require that the material being "read" be prepared in a special manner; that is, for example, as holes in cards. In the same manner that we expect that words be printed on paper using the Roman alphabet in the English language (usually), so the input device of the com-

puter has its normal language of communication, holes in cards.

Some computers can read directly from the printed page of a book or paper, a system known as Optical Character Recognition (OCR). The U.S. Post Office is developing machines for reading the addresses on letters so that mail can be sorted and distributed automatically. To speed the handling of bank checks, special magnetized printing on the checks can be read by computers. This is known as Magnetic Ink Character Recognition (MICR).

Upon receiving information from the input device, the computer must know the difference between what is an instruction to do something and what is data to be used in the calculation. On the basis of the instructions given and the answers produced, decisions are to be made on what to do next. In the human system, this job is performed in the brain, the information to help make the decisions being saved in the memory. In the computer, a special unit of the system called the *control unit* is capable of making some very easy decisions and thus controlling the next operation of the machine. The data used in making decisions are stored in *registers,* which are readable (*accessible*) by the control unit. The control unit also contains *wired-in* (prewired electronic circuits) instructions telling how to do many complicated things; for example, how to compute a square root, multiply, divide, or what to do if something goes wrong.

The optical nerves which connect the eye with the brain and the motor system from the brain to the muscles of the arm and hand also have counterparts in the electronic computer system. These paths are known as *channels* and are mini-computers themselves having sufficient knowledge and "know-how" to do just their job.

The arm and hand in the human system were used to perform two basic tasks: (1) holding the pencil over the paper and (2) the hand was able to record (remember) information which was viewed by the eye. This information could have been obtained either from the homework sheet, the notes, the rough work sheets, or the adding machine. The recording of this information on the rough work sheets is like storing information in the memory of the machine. Different from the registers which are part of the control unit, the memory of the

computer is *general purpose* and is used to save data not being used in the computations at that moment. The hand and arm also rewrite data from the human memory to the answer sheet, thus performing the process known as *output.*

The devices used by the computer to communicate with the "outside world" vary greatly from a simple typewriterlike device, through high-speed printing devices (almost like printing presses) to television-style consoles and telephones. The printed style of output is the most common form since it provides a lasting copy of the computational results. Some high-speed printing devices can print 1,500 lines of information per minute, each line consisting of up to 150 characters (letters, numbers, special characters, and spaces). This pamphlet contains about 50 lines on each page with about 55 characters on a line. Even the typewriterlike devices can type at 10 to 15 characters per second, which is a great deal faster than a person can type.

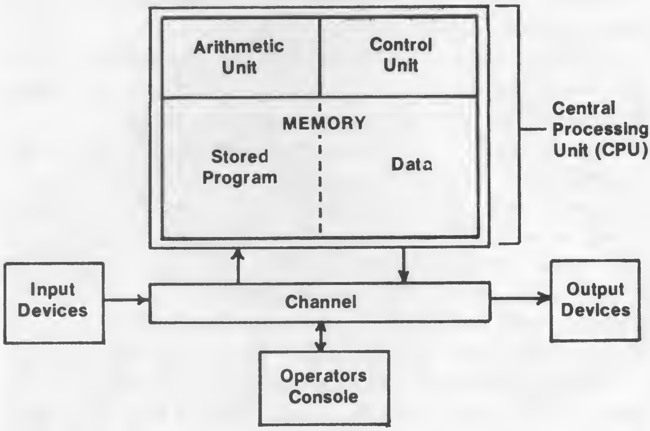
Television-style devices (Cathode Ray Tubes or CRTs) can show a programmer a small amount of information in a very short time without the need for printing on paper. Some CRT devices can only show letters and numbers, but others can actually make drawings and pictures. Due to the high speed of computers, the speed of making drawings can be used to make movie cartoons or mock-ups of actual happenings. By using a CRT, pilots can be trained to land aircraft on short runways or aircraft carriers without ever getting into a plane or even leaving the ground! Before the first moon landing by Apollo 11, NASA used computerized color TV to simulate the moon's surface for use in the computerized LEM training system. Thus, astronauts were trained to go where no man had ever been before. Plotting devices can also be attached to a computer to make copies of engineering drawings of objects which were designed by the computer. Some artists also use these devices to make pictures or to show how a sculpture should be made.

At the American Stock Exchange, one of the outputs from a computer is a recorded voice over a telephone. Recordings were made of a person saying one word at a time. The computer can then answer questions about stock prices by forming the recorded words into sentences, which are then sent over the telephone.

Finally, the adding machine which was part of our

human computing system is to be replaced by the arithmetic unit of the electronic computer. This unit is very simple, but extremely fast. Usually, the arithmetic unit of a computer is capable of doing only one task: adding two numbers. However, under the supervision of the control unit, the arithmetic unit can subtract by "reverse addition," multiply by "repeated addition," and divide by "repeated subtraction." Larger modern machines can add two numbers together in less than one millionth of a second (a *microsecond*).

Because this unit can work so fast, it is not economical for a computer to wait for a human to tell it what to do at each step of a process. By the time you have noticed that the machine has finished the last task you gave it (which usually takes you about one-third of a second), thousands of calculations could have been done. Hence, to work efficiently, the instructions which tell the machine how to solve a problem must be available to the computer at its own speed. Thus, the idea of Von Neumann to store the instructions within the machine is very important to the efficiency of computer usage. The instructions (program) are stored in the memory of the computer along with the data to be used, intermediate results (rough work), and the final results (before output).



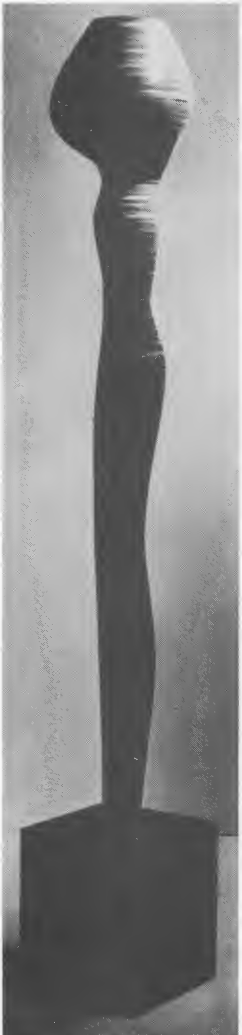
The Uses of Computers

Internal Revenue Service.—In the past few years, the Internal Revenue Service has become highly automated. Computer centers have been established in major cities throughout the country.

Tax return information for many years is kept on file by social security numbers of citizens. When a person files a return, a computer checks all entries for completeness and checks the taxpayer's arithmetic and his deductions to make sure they are not higher than they should be.

If errors are found or if a person who has earned a salary does not file a return, the computer lets the IRS know about it.

Tranz computer sculpture in laminated veneer by Robert Mallary



Education.—Computers are finding growing acceptance in education. They are used in the classroom primarily as teaching and grading devices.

Teaching machines now offer programmed instruction in which a student need never see a human teacher to complete a course. Both questions and answers are stored in the computer's memory. A student need only type his answer or make a choice in a multiple-choice quiz. The computer then analyzes the answer. If it is correct, the machine moves on to the next question. If it is wrong, the machine directs the student to the area where the solution can be found. In this way, a teaching machine can lead a student through a course, taking each area of learning step by step.

Simple computers have been used for many years to grade papers for multiple-choice quizzes.

Computers don't just help with the educational process. They are "students" themselves and can be taught to learn from mistakes and successes.

Programs have been written for computers to enable them to successfully play ticktacktoe, checkers, blackjack, and even chess. If a chess-playing computer makes a bad move during a game, it will remember that move and never make it again. In this way it can be said to learn. The computer does this by breaking down the problem into its smallest components, just as a human student handles a mathematical formula.

So far, computers can play only a mediocre game of chess. They are no match for masters. In fact, they can be no better than the human who programmed the game.

Computers are used to help students refine their skills in math and science. These instructional systems allow the student to work at his own speed.

Law.—The number of legal documents in existence today is so immense that no lawyer can possibly hope to examine them all without help, and so the laws and court decisions have been classified by the computer. A lawyer simply inquires of the computer by giving it key words or phrases, and the computer immediately gives him a list of cases and decisions bearing on the question he is concerned with.

Medicine.—Digital computers are used in diagnosis and in compiling information on diseases which may lead to new breakthroughs in medicine. Doctors may soon have a catalog of more than 10,000 diseases to check their diagnoses against.

Other computers, mostly the analog type, are often used to monitor the bodily functions of critically ill persons. Measuring devices are attached to the patient and connected directly to a computer that can keep a constant check of pulse, heartbeat, brain waves, etc. The slightest change in the patient's condition is reported immediately, often before there is any visual sign of change.

Transportation.—Computers are being used to figure the best load for a truck, train, ship, or aircraft. They help management determine the best route to take and even advise the managers what number of vehicles they need to make the most profit. The superspeed trains being developed today must be controlled by computers.

Computers used in many phases of medicine.

Computer terminals like the one shown at left are installed in many small hospitals and linked by telephone lines to the main computer. With this system doctors in rural areas have access to the latest treatments for many diseases.

Computers are used to find fingerprints quickly, see below.

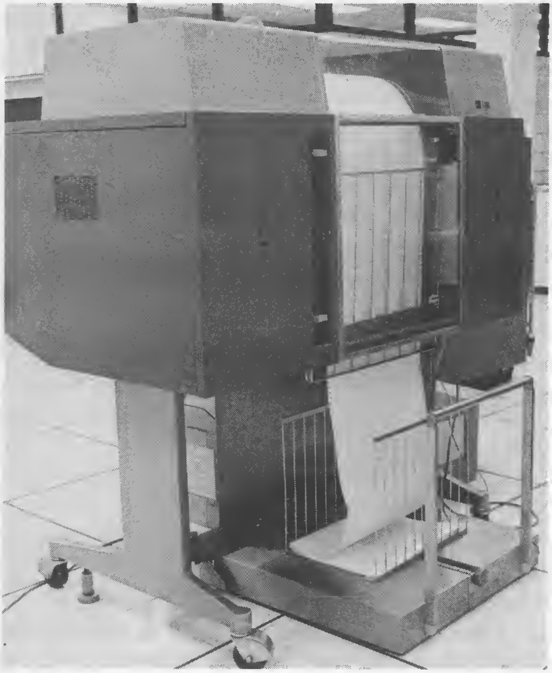
Traffic Control. — Most large airports now have computers to assist the air traffic controllers in organizing the takeoff, landing, and holding of aircraft in the area. At the same time, the computers are fed the routes, airspeed, estimated takeoff time, etc., of aircraft requesting approval of flight plans. Combining these with the weather forecasts, the pilots are given the best routes for their flights. For automobile traffic, computers are used to control the traffic lights in cities. They can be programmed to change the timing of the traffic lights according to the volume or direction of traffic or according to a predetermined interval.

Space.—There could be no man-in-space program without computers. At every step in preparation for a space shot and during the countdown and the flight itself, computers are busily making the instant calculations that are necessary.

Weather Forecasting.—The U.S. Weather Bureau and the Air Weather Service make use of computers in forecasting. Meteorological observations are taken hourly at stations allover the country. To keep forecasts up to the minute, the U.S. Weather Bureau relies upon computers for analyzing the great number of factors that must be considered in hourly forecasts.

Telephone Switching.—With the ever-increasing number of telephones being installed for both business and residence and millions of calls being made locally and cross-country, the telephone companies have to rely on high-speed, electronic switching systems. These systems are high-speed computers developed by Bell Telephone Laboratories for this specific purpose.

A Univac computer system in operation.



The machine shown on the left prints addresses on 45,000 *Boys' Life* mailing labels in about an hour.

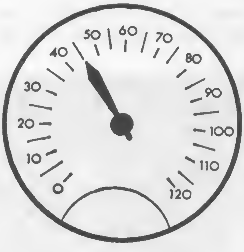
Computers, as pictured below, are used to confirm airline reservations.

How Computers Differ

We can find out how the two types of computers differ by examining the words they come from. The word "analog" is derived from the word "analogy," which means to make a comparison between things that are not very similar in themselves. If you say "A Scout is like a fencepost, straight and strong," you are making an analogy. Very few Scouts look like fenceposts, but the analogy is true because most Scouts and fenceposts share the attributes of being straight and strong.

The word "digital" comes from the Latin word "digitus," meaning finger or toe. It still means finger or toe to a zooligist. In mathematics it means a figure from 0 to 9.

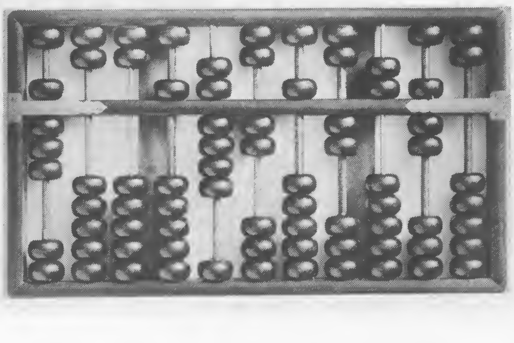
The words "analog" and "digital" suggest the basic difference between the two types of computers: An analog computer compares any two things and gives an approximate measurement; a digital computer counts figures and gives an exact total.



Speedometer

Simple Analogs.—One of the most familar analog devices is the speedometer in your family car. As the car's wheels rotate, a message is sent to a device under the dashboard. This device transforms the message into a reading on a dial. It is an approximation only, and its accuracy depends on how good the speedometer is. If the dial reads 50 miles per hour, the car may actually by traveling 48 or 52 mph, but a good speedometer gives a very close approximation.

Simple Digital Computers.—The first digital computer was the abacus. All digital computers deal directly with digits or numerals, not with quantities or other measurements.


A Chinese abacus

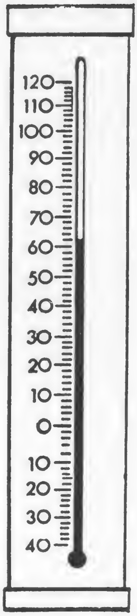
Modern Analog Computers.—Well, you might say, digital computers are more accurate than analogs, so why bother with analogs at all? Why not use only digital computers?

The fact is that digital computers are gradually supplanting analogs in most fields, but analogs still have their uses because they have certain advantages. Analogs are usually simpler. Consider the thermometer, a simple analog device. A digital computer could be built that would record temperatures, but it would not likely be as simple. Another advantage of analogs is speed: This is because the analog is measuring the operation *as it happens.*

The analogs that we have mentioned so far have been such simple devices as speedomemters, slide rules, and thermometers. But you'll find that there are very complex analogs, almost comparable in complexity to their digital cousins.

Many very complicated analog computers are now used in aircraft design, in controlling the flow of electric power, in controlling automatic machining processes, and in other applications where simultaneous monitoring of the work is necessary. Analogs are also very useful in chemical plants and petroleum refineries where each step of the work must be under constant control.

Summing it up, we can sat that analog computers have the advantages of simplicity and speed in certain applications. Their disadvantages are less accuracy than digital computers and the fact that most analogs are specialists—they do only one job.



Thermometer

Modern Digital Computers.—Basically, the digital computer has no intelligence whatever. About the most complex thing it really knows how to do is add 1 and 1. All of its mathematical genius is really just repeating that addition of two digits, but it does this at such lightning speed that it is capable of millions of such additions a second.

Digital computers are adapted to new uses every day because of these advantages over the analog computer.

- Greater accuracy
- More flexibility of purpose
- More compactness
- They can handle problems of logic that are beyond the analog.

The digital computer suffers in comparison with the analog computer only in the fact that for some purposes the analog computer will give an immediate answer to a problem that might take the digital computer a second or two.

Special- and General-Purpose Machines

Computers can be classified by the tasks they are designed to perform. Large general-purpose machines in service centers must be capable of performing the many different tasks required by the center's clients. Such machines are often much larger than is necessary to solve any particular problem and thus much more expensive than a machine designed for one specific purpose. The invention of microcomputers at a low cost permits the exclusive use of a single computer for a single task.

Where a computer will be asked to solve one special type of problem, it is better to design a computer for that one task than to use a machine that was designed to solve all kinds of problems. The computers that "fly" with the astronauts are special-purpose machines and, thus, are very efficient at their particular task, but may be totally useless for anything else, such as playing chess.

The ancient Britons found themselves in the same situation. They built a very special computer to predict the times of eclipses. This computer we know as Stonehenge, and it is obviously not of much use for computational purposes other than predicting the occurence of eclipses. Given sufficient time and energy, a human using an abacus could have solved the same problem. Many analog computers are special-purpose, machines, and some digital computers—which were designed as general-purpose systems—become special-purpose when they are *tied in* to other equipment. For example, in hospitals, a general-purpose computer is attached to monitoring devices which "watch over" the vital signs of a patient. In this use, these machines cannot (dare not) be used for any other purpose and, thus, have become special-purpose.

Many companies now sell "personal computers" for home use. Usually these use a microcomputer and are general-purpose.

A digital computer and analog computers work together to form a system used to "fly" helicopters that are still on the drawing board. The system allows engineers to design, develop, and test — on the ground—better and safer helicopters.

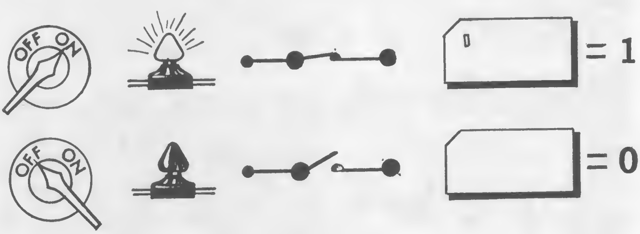
Computer Programs

2. Do the following:

a. Tell what a program is and how it is developed.
b. Explain the difference between an assembler and a compiler. Tell where each might be used. Describe a source and an object program.
c. Use a flowchart diagram to show the steps needed to set up a camp.

In order to use a computer to solve problems, a person must prepare in advance a detailed set of instructions for the computer to follow. The instructions are known as a *program* and must be complete in every way. Every possible eventuality must be taken into account by the person writing a program so that the machine never gets into the situation of not knowing what to do next. A computer does not understand the statement "You know what I mean." In fact, once you have programmed a problem and executed it, the computer has to be told again the next time the same type of problem is to be solved.

One more complication: The computer has a language all its own and insists that all communications be in that language. That language is one with an "alphabet" of only 1 and 0. Like the Morse code, a language with an alphabet of dots and dashes, the particular patterns of 1's and 0's have particular meanings to the computer.



How binary numbers are expressed electrically

Clever computer scientists have solved this problem by writing programs that "understand" humanlike languages and that translate programs written in those languages into the special language of the computer. Messages and answers from the computer can be inter-

cepted by special programs and converted into terms familiar to us at output time. For example, although the machine works only with 1's and 0's (the binary number system), we are used to seeing numbers written in decimal notation. A program has been written to automatically convert from binary numerals into decimal numbers and then print on an output device.

A program is developed in three stages:

a. A description of the problem, usually written in English. This may be provided by the person wanting the problem solved and explains how he would go about solving the problem if he had to do it by hand.
b. A description of how the computer would solve the same problem. This description usually takes the form of a diagram (flowchart) that identifies each step to be taken in the solution of the problem and the decisions to be made at each step.
c. The writing of the program, usually in special humanlike language (programming language), which is sent to the computer for translation into the computer language.

This last stage is followed by testing the program with some known data and results. A program very rarely works the first time since there are so many instructions and the possibility of human error is always high (even in just typing the program). This process of correcting the program is known as *debugging* (getting the bugs out).

Assembler and Compiler

Programming languages were invented to aid nonexpert programmers to express the solution to their

problem in a manner which did not require them to also become computer experts. A computer user has enough trouble writing a program without writing in a foreign language.

The historical development of programming languages has become a three-step process. Originally, a programmer was forced to understand the electronic workings of the computer in order to design a program which would solve his problem. This program was written in *machine language* and consisted of 1's and 0's (known as *bits*, a term derived from **b**inary **digits**) which had to be placed in the memory of the machine at exactly the correct positons. This was extremely hard, and, although many aids were constructed to help, a programmer had to be an expert electronic engineer to perform his task.

At the next step, a program was written that would take a set of sentences written in an English-like language, each describing a *single* step in the solution of the problem. These were then translated into the actual language of the computer (machine language). This new language was known as *assembly language,* because the program to translate it assembled machine language. This was a vast simplification over writing programs in machine language. Now the programmer could write ADD (for add) or DIV (for divide) instead of having to remember the binary code in the machine language for those instructions. The translator of an assembly language is known as an *assembler*.

As machine designs improved, it was found that each type had its own machine language and, hence, its own assembly language. Thus, a program written for one machine could not be used on another machine of a different manufacturer. To overcome this problem, languages were invented that were "machine independent." These early languages were even closer to the English language than assembly languages, but they referred to mathematical problems rather than everyday problems. In this style of language, a mathematical expression can be written in a form such as D = A + B instead of the assembly language sentences (to be taken in order) GET A; ADD B; IS D. The program that translates higher level language into machine language is known as a *compiler.*

Source Program and Object Program

The program that the programmer writes to express the instructions on how to solve a problem is known as the source program; the program that results from translation either by an assembler or by a compiler is known as the object program.

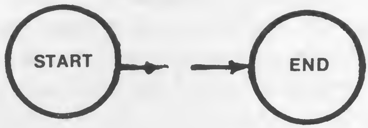
As with general- and special-purpose computers, programming languages can be classified. At the higher level, many languages exist that are general-purpose and are designed to assist in the description of many types of mathematical problems. Specialized programming languages have been developed to help engineers and surveyors program particular problems. These languages are not generally suited for any use other than that for which they were specifically designed, but they enable the engineer or surveyor to express the solution to a problem in terms he is familiar with.

Today we consider all assembly languages as being special-purpose since each computer manufacturer uses them to write compilers for higher level languages that are accepted standards in business and industry. Also, assembly languages are used as special-purpose languages to write programs that provide the means to solve problems rather than solving problems themselves.

General-purpose programming languages: FORTRAN (**For**mula **Tran**slation), ALGOL (**Algo**rithmic **L**anguage), PL/I (**P**rogramming **L**anguage **I**), BASIC (**B**eginner's **A**ll-Purpose **S**ymbolic **I**nstruction **C**ode), COBOL (**Co**mmon **B**usiness **O**riented **L**anguage). Special-purpose programming languages: COGO (**Co**ordinate **Geo**metry), ECAP (**E**lectronic **C**ircuit **A**nalysis **P**rogram), LISP (**Lis**t **P**rocessing Language), STRESS (**Str**uctural **E**ngineering **S**ystems **S**olver), TUTOR (A language for preparing computer-assisted instruction (CAI) courses under the PLATO system.

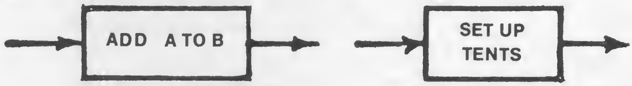
Symbol for start or end

Examples



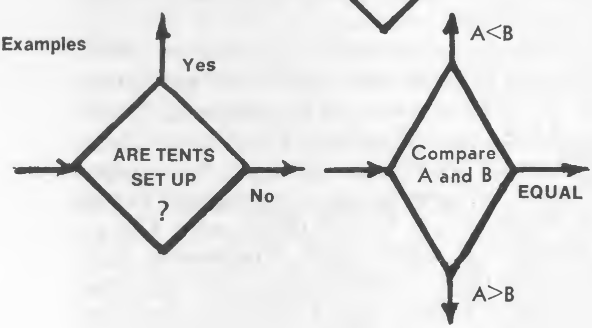
Symbol for an action, process, function, or step

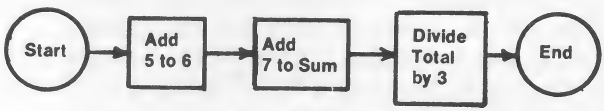
Examples



Symbol for decision making

Examples





A Simple Flowchart

Flowcharts

3. Do one of the following:

a. Prepare flowcharts to find out the average attendance and dues paid at the last five troop meetings.

b. Prepare flowcharts to work out a simple arithmetic problem. Explain to your counselor how this program could be stored in a computer. Tell how it could be used again.

Prior to programming, a programmer will make a flow diagram or flowchart of the logic required to solve a problem to ensure himself that the computer will be fed the proper instructions. A flowchart also breaks the problem down into simple steps just as you would have done it if you were to solve it in your head.

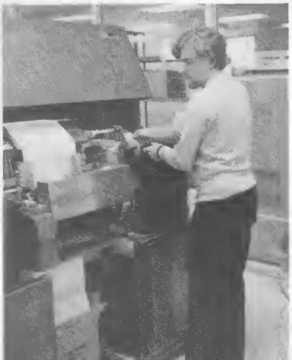
A flowchart is a picture or diagram of the steps required to solve a problem presented in a few simple geometric symbols.

Campsite Setup. — To set up a campsite is not an arithmetic problem but a problem of logic. Your flowchart will have directions, questions, and answers rather than digits.

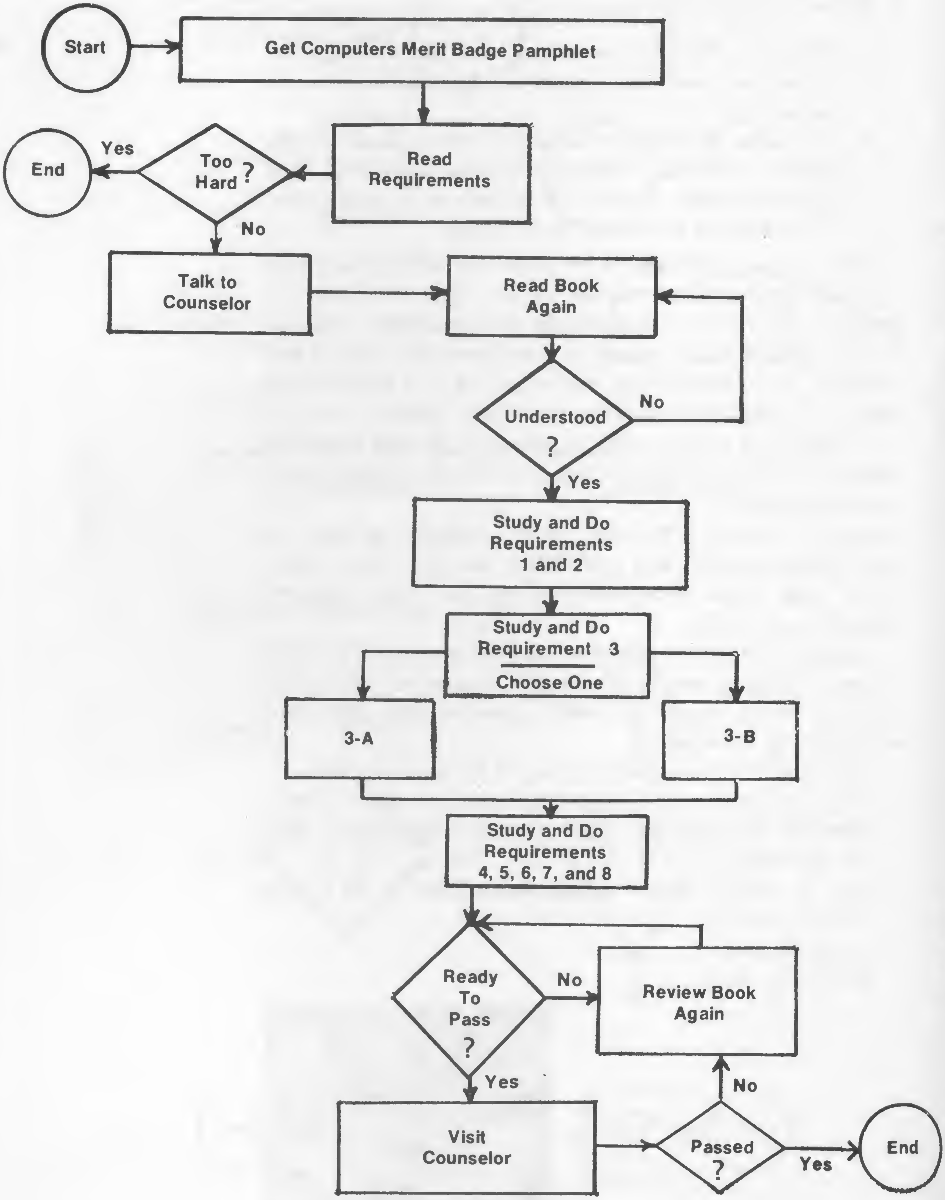
Keep in mind that many steps may seem self-evident to you, but they would not be to a computer. You must consider every move and every question that goes into establishing a campsite.

Here are several steps that ought to be included:

- Step 1—Choose site for patrol camping. Specify reasons for choosing site. Have patrol unpack gear and set up tents.
- Step 2—Patrol leader designates chores to do before anyone can eat:
  Fetch firewood.
  Build fire site.



Flowchart for Computers Merit Badge



Fetch water for fire buckets.
Cooks prepare meals.
Start fire and cook food.
Have remaining Scouts clean up area and set up eating area.

- Step 3—Food is divided up and all eat.
- Step 4—Divide patrol into buddies.
- Step 5—Dig latrine, if needed.
- Step 6—Buddies clean up dishes, gather more firewood, and get drinking water.
- Step 7—When all is completed plan other activities for remainder of camp-out.

Types of Storage

Let us first look at the available devices for building a storage system. There are four basic techniques of providing storage in use today: core storage, drum storage, disk storage, and magnetic tape storage. Each of these storage devices is like an input *and* an output device, receiving and returning information.

All four devices are designed to use the principles of electromagnetism, that is, the laws that govern electricity and magnetics. You know that if you get lost on a hike you can pull out your compass and find North because the needle will line up in a north-south alignment. This happens because the needle is attracted to the magnetic North Pole. If it were possible to switch the earth's North and South Poles, the compass needle would reverse itself and point in the opposite direction. Although this can't be done, it is possible to reverse a magnetic field electrically. This property of electromagnetism is used to give memory to a digital computer.

Core Storage. — Magnetic core storage is the most widely used type of memory device because it permits the storing of great amounts of information in a small space and because each bit of information is easy to find.

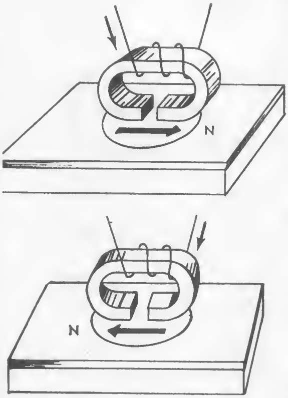
Magnetic cores are tiny, doughnut-shaped rings of ferrite (iron compound) material a few hundredths of an inch in diameter. They look like the small beads you would use for an Indian belt or headband. More than a million cores are used in large computers. They are woven together somewhat as you would weave Indian beads, but several wires run through each core. Each

core is magnetized in either a clockwise or counterclockwise direction, and the direction of its magnetism represents one bit of information for the computer (either 1 or 0, yes or no, etc.).

When the proper pulse of electrical current is sent on a wire through one of these ferrite cores, the core reverses its magnetic field. (1 becomes 0, 0 becomes 1, etc.). The computer can store information in any one of a million cores by dividing the electrical current needed to reverse its magnetic field and sending half of it through the proper vertical wire and half through the horizontal wire. Suppose we want to store 1 or 0 in the core at the intersection of vertical wire 71 and horizontal wire 37. Half the current needed is sent through wire 71 and half through wire 37.

To *read* the information that has been stored in the core storage there are *sensor wires* interlacing all the cores. These are able to communicate to the computer the status of each core (whether it is in the 0 state or the 1 state). The process is more complicated than it sounds, but it is still an instantaneous *reading*. The assembly of wires and cores is called a *core storage plane.*

You can build a simple model of a *core storage plane* to explain how it works by stringing beads or washers on wires attached to a wooden frame. This will be a nonworking model, of course, but it will help you visualize core storage operation.



A magnetic field can be changed electrically.

Memory cores are magnetized to store information.

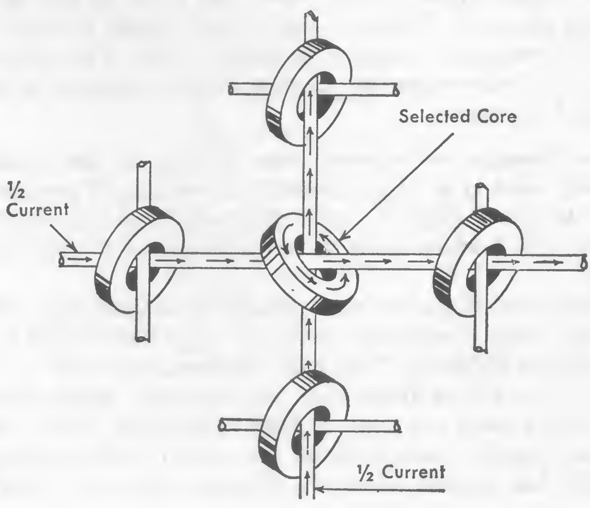
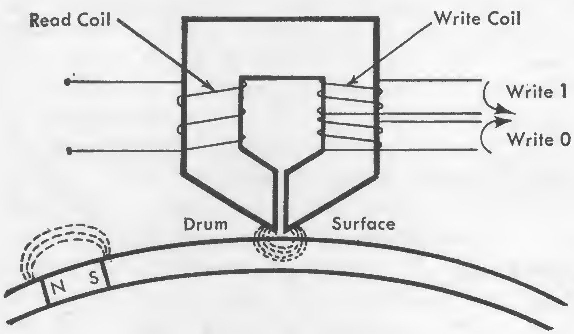


Illustration at right shows how electrical impulses affect the core magnets in storage.

Rotating Storage Devices. — If we put a tiny spot of magnetic material on any surface, it will act like a magnet. If it is placed in a strong magnetic field, it will align itself with that field. If we change the direction of the field by using an electromagnet, the tiny magnetic spot will change its direction too. The direction of this spot, then, can represent one bit of information for a computer.

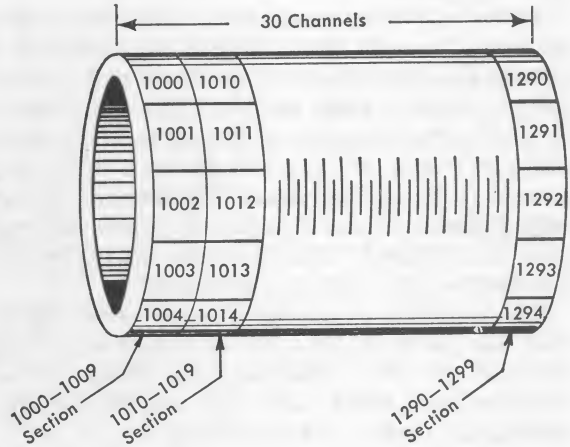
To see how this works let's move our magnetized spot past the ends of a U-shaped iron core with a coil of wire attached. Since the spot acts like a permanent magnet, it has a small magnetic field of its own. Thus, by moving the magnetized spot through the same electromagnet with which we magnetized it, we create a current in the electromagnet. The direction of this current depends on the direction in which the magnetic spot was aligned. Therefore, the computer can tell whether the spot represented 1 or 0.

The computer can read, write, or erase (by writing 0's) one bit of information on each spot of magnetic material. On drum, disk, and tape storage devices, the electromagnet which does the reading, writing, and erasing is called a *read-write head.*



Magnetic "read-write" head, above, stores information on the drum and "reads" it on command of the machine.

Magnetic Drums.—Magnetic drums are rotating metal cylinders marked off in parallel bands or tracks. Each track may be spot-magnetized in either direction by an electrical impulse. A *read-write head* above each track serves as a recorder and sensor. Magnetization in one direction will represent a "1," while in the other it means a "0."



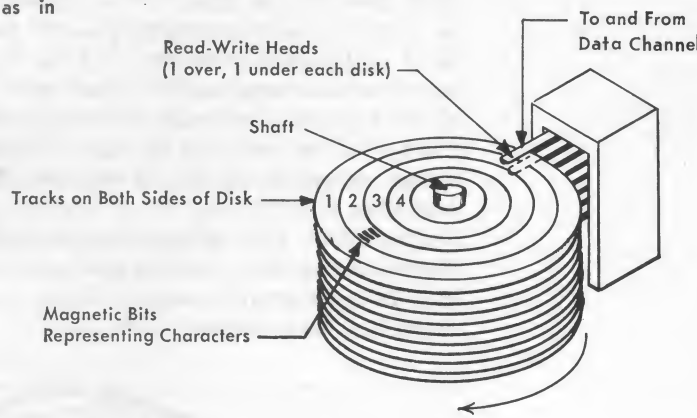
Bits of information are organized for storage on a magnetic drum.

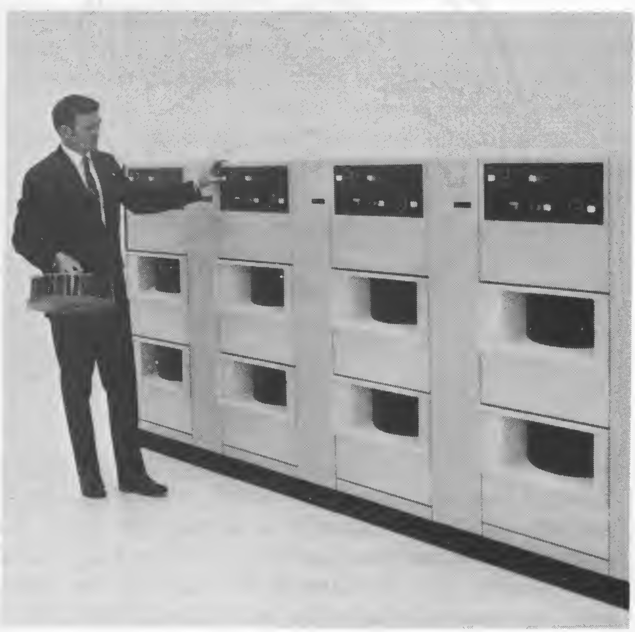
Magnetic Disks.—Magnetic disks operate the same way as drums. They look like phonograph records and rotate in the same way. The disks are made of metal, and their surfaces can be spot-magnetized just like the tracks on the magnetic drum. Several read-write heads may be positioned along the radius of the disk so that data can be read and recorded quickly.

Some magnetic disks have an advantage over both drums or core memories: They can be removed from the cabinet and replaced like phonograph records. Information can be stored on the disk for use at a later date, and the disks can be put into a "library." Disks can be labeled by the operators and placed on shelves until the next time the computer needs that particular information. For example, if a company only runs its payroll calculations once a month, there is no need to have the information of salary rates of all the employees available all the time. Only when there are changes in employees or when someone gets a salary raise or when the payroll checks are to be produced is that particular disk needed in the computer system. The rest of

the time, when the computer is doing other tasks, other disks can be installed, thus expanding the effective storage capacity of the computer.

In disk storage, information is stored on disks and read back as in drum storage.

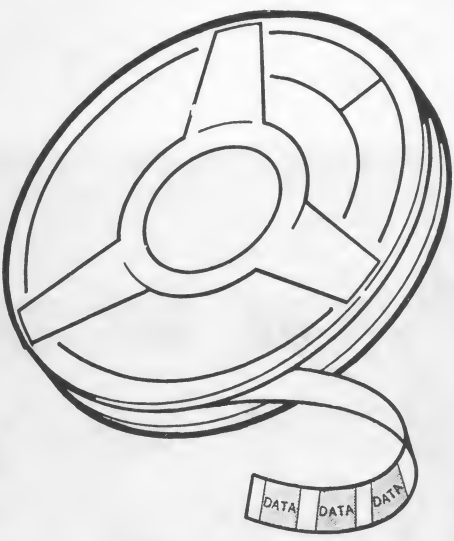




A disk storage system

Magnetic Tape.—The material used in magnetic tape units is flexible but otherwise acts just like the magnetic material used to build drums or disks. This tape is much like that used in your home or school tape recorder, though it is wider (usually ½ inch) and moves much faster past the read-write heads. Magnetic tape is wound onto reels, each reel containing as much as 2,400 feet of tape. Since 500 characters can be stored on 1 inch, it is theoretically possible to have as many as 14 million characters on one tape. In fact that number is reduced considerably, since gaps have to be left at the beginning and end of the tape to allow it to be fixed onto the reels and through the machine, and between recordings so that it can stop before the next recording is read.

Like disks, reels of tape can be removed from the computer and, thus, provide enormous storage capabilities. Many computing centers have magnetic tape libraries of information.



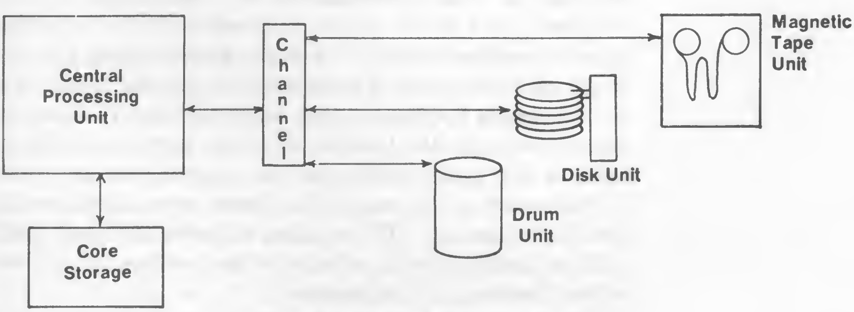
Organization of a Storage System.—The cost of providing storage in a computer is the price of the equipment divided by the amount of storage provided. The units of measurement are usually *cents per bit*. In order of decreasing cost, the storage devices are core, drum, disk, and magnetic tape. By coincidence, this order is

exactly the opposite of the list made if the devices were arranged according to speed in providing information.

Speed is measured as the time it takes the central processing unit to begin receiving information from a storage device after requesting that information. This delay occurs due to several factors. In the core storage, the circuits must be set up to select a particular core. In the drum and on the disk the read heads are fixed in position, and, thus, the computer must wait for the device to rotate until the recording needed is under the read head. Also, on the disk the read heads must be moved vertically to select the particular disk in the set and horizontally to the position on that disk (called the *track*) of the information. When using a magnetic tape, the heads remain in one position, and tape must be moved past them to get to the right position. Also, when using both removable disks and tapes the correct storage device may not be on the system, and, thus, the computer must wait until the operator has installed the proper device.

Based on the cost of the devices and the time it takes to get information, a scheme can be invented for the storage of different types of information:

- Core storage—programs and data actually in use.
- Drum storage—permanent programs (including compilers and assemblers) which are used very often.
- Disk storage—programs and data which are used regularly but which are not always necessary for the operation of the computer system.
- Magnetic tape—infrequently used programs and data or new programs and data which are being given to the system for the first time. Also used for permanent copies of the programs and data stored on the drum in case anything goes wrong.



A Multilevel Storage Scheme

Input/Output Systems

4. Do the following:

a. Name four input/output devices for computers. Explain the use of two of them in a system.
b. Explain the Hollerith code. Show how your name and address would be punched on a card.

The three communications systems which we shall consider are the printed word (numbers and words in a written language), pictures (words and numbers represented by diagrams), and sound (words and numbers in an audible language). Each of these communications systems can be used either to transmit information *to* a computer or to transmit results *from* a computer.

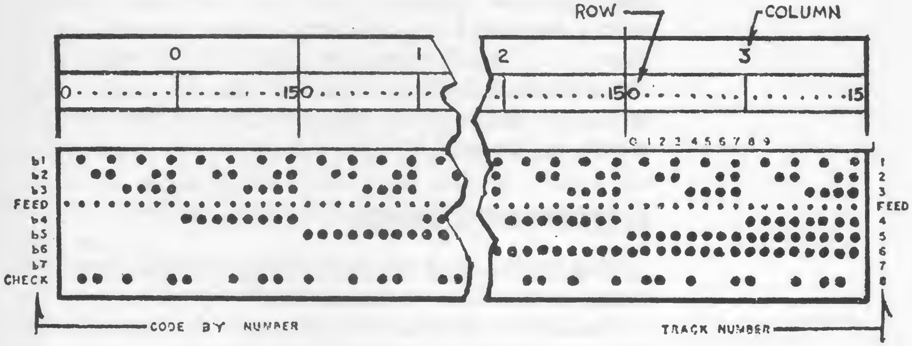
Printed Word

The most common form of input/output system connected to a computer is the printed word. From the very first, even as far back as the Jacquard loom, the communication of information to the computer has taken the form of the written word. Unfortunately, the ability of a computer to "read" a page of writing or printing has not been developed to the stage where it is always available. Thus, we are forced to use communications systems which are more closely geared to the computer than to our own methods of communication. Thus, the "printed word" for input to a computer often takes the form of holes punched into paper.

Two standard forms of *punched* input are available: the punched card and punched paper tape. Each form consists of the representation of characters (letters, numbers, and some special characters such as period, comma, and semicolon) as holes whose codes the machine can recognize. The original data processing card was designed by Dr. Herman Hollerith and is the same size as was the 1890 dollar bill. The horizontal dimension of the card represents the message to be transmitted, and each vertical column represents an individual character. The number of holes and their position in each vertical column is the coding for a character. See diagram on page 45.

Whereas a card can contain only a certain amount of

information because it is a fixed length, a tape can be as long as the programmer needs. It is usually made of paper, although plastic and foil have been used. The length represents the message, and the width contains the punched code for individual characters of the message.



The devices to *read* cards or tapes can be either electromechanical or photosensitive. The simplest form is the electromechanical system, in which the holes and their positions are determined by metal "feelers." When these "feelers" drop through a hole they complete an electrical circuit and send a signal to the computer.

In a photosensitive reader, the card or tape is passed under a light source and over a set of photocells. When the light passes through a hole, the photocells react and send a signal to the computer.

Computers have printing devices that convert signals into printing on paper. The simplest form of printer is the *teletype®* which is like a special form of typewriter. In this device the electrical signals from the computer turn a cylinder to face the paper, print the character on the front, and then move the cylinder to the next position on the paper.

This kind of printing device is slow compared with the speed of the computer in getting answers. Thus, high-speed printers have been developed which are capable of printing a whole line at one stroke. Like the teletype, the *line printer* has all the characters that are possible to be printed etched on chains or wheels or cylinders. As the signals arrive from the computer, each wheel in the line is set to the required character. When the whole line is set up the line gets printed on the paper. Some high-speed printers have been built which

®RTM Teletype Corporation, Skokie, Illinois.

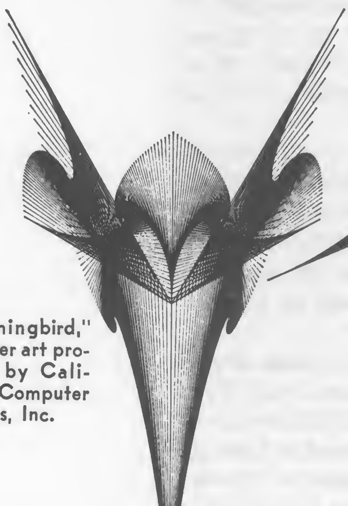
are not mechanical but *print* by burning or spraying ink on the paper. Others use special photographic paper and a high-intensity light to create images of the characters on the paper which is later developed.

The printed word can also be input to a computer from a page through a device known as an OCR (**O**ptical **C**haracter **R**ecognizer). This device can actually *read* a page and tell the central processing unit what it saw. In some devices, special printing is required on the page to help the reader interpret. In common use today are the magnetic ink characters on bank checks, which can be read both by a human and a machine.

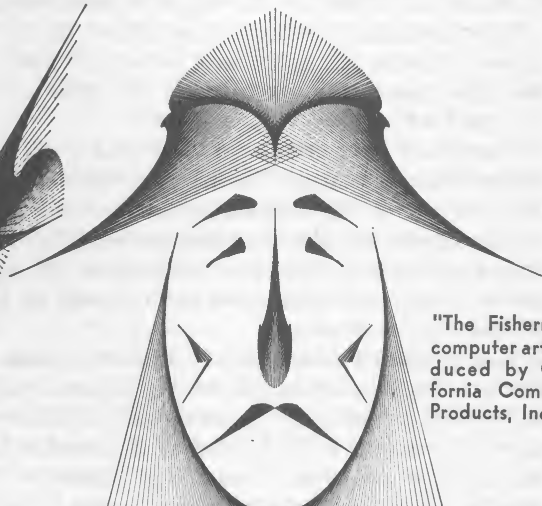
Diagrams and Drawings

The second type of input/output system uses diagrams or drawings as communication.

One kind of plotter simply consists of a sheet of paper on a movable drum on which the computer draws with a pen. While the drum can move the paper forward and backward, the pen can be moved sideways as well as lifted off the paper. By moving the drum and pen together, the plotter can draw lines at almost any angle. By careful programming, the computer can make en-



"Hummingbird," computer art produced by California Computer Products, Inc.



"The Fisherman," computer art produced by California Computer Products, Inc.

gineering drawings and even produce works of art.

Based on the same principle as the plotter, a televisionlike device can be attached to a computer. This device, used previously by engineers and physicists, is known as a CRT (Cathode Ray Tube). In a CRT, an electron beam can be controlled to illuminate the face of the tube in the same way as the pen was controlled on the plotter. However, the speed at which the electron beam can be controlled is much faster; thus, pictures or diagrams can be produced in fractions of a second. If produced fast enough, the pictures appear to move, like on a home television screen. Whereas the plotter is useful to the engineer to make drawings, the CRT is used by cartoonists and animators to produce movies.

Both the CRT and the plotter are output devices, but the ingenuity of the computer scientist also turned the CRT into an input device. Using the photoelectric cells, a special "pen" was developed which is capable of detecting light on a CRT. Using a CRT, a special program, and a *light pen,* a computer user can "draw" on the screen of a CRT and give his problem to the computer in graphic terms rather than the written word.

This was developed for scientists and engineers who need fingertip access to a computer. With an electronic light pen, a user can revise diagrams and through the keyboard change information and images on the screen.

Sound

The third communications system is communication by sound. Like graphic communication, the invention of an output device utilizing sound signals came before the invention of an input device. Much research is being done now on vocal input to a computer, especially for use in space. It would be far easier (and less prone to error) for an astronaut to speak commands to a computer than to have to set all kinds of switches. Some special-purpose machines have been built that are capable of understanding instructions spoken by a human, but they tend to have a very small vocabulary.

With the introduction of the touch-tone telephone by the Bell System, it is possible to transmit information to a computer through the keys of the telephone and to get a vocal reply. The depression of a key (button) on a touch-tone phone sends a signal in the form of a particular tone. In some areas, these touch-tone phones are being used experimentally in helping students with their homework. Questions can be asked about mathematical problems by the computer and the answer sent back through the keys or questions can be asked that have multiple-choice answers.

A portable audio terminal built into a briefcase allows a person to "talk" to the computer at his company office through any telephone.

Hollerith Code

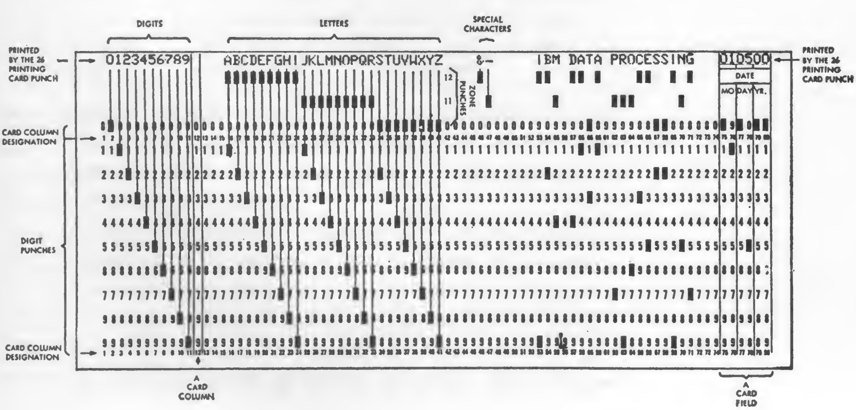
Herman Hollerith developed the first data processing machine used on a major scale to handle the data from the 1890 census. His punched-card system is still in use today, and the code for his cards is known as Hollerith or standard ANSI card code.

HOLLERITH CODE

						Numbers	
A	12-1	J	11-1	S	0-2	0	0
B	12-2	K	11-2	T	0-3	1	1
C	12-3	L	11-3	U	0-4	2	2
D	12-4	M	11-4	V	0-5	3	3
E	12-5	N	11-5	W	0-6	4	4
F	12-6	0	11-6	X	0-7	5	5
G	12-7	P	11-7	Y	0-8	6	6
H	12-8	Q	11-8	Z	0-9	7	7
I	12-9	R	11-9			8	8
						9	9

Look at the sample card in the diagram. It has been marked with special lines to show how the keypunch operator indicates numbers or letters using the Hollerith code. There are 80 up-and-down columns containing 10 numbers from 0 through 9 inclusive. At the top and middle of the card you will see the numbers 11 and 12, which are called zone punches.

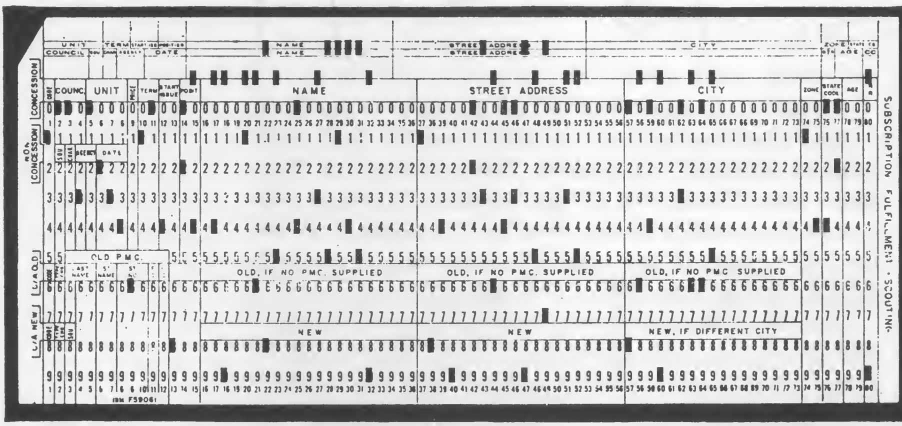
If you look along the top edge of the card, you see how the card punch operator can record numbers by punching the actual numbers (digits). Then, by punching a zone punch above (12 for A to I, 11 for J to R, and 0 for S to Z) and a number below, he can record any letter of the alphabet.



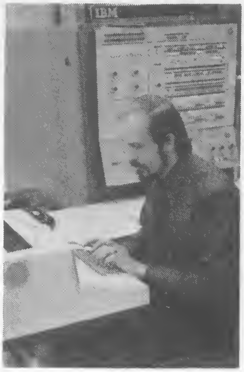
Look at the card that was used to record information about a *Scouting Magazine* subscriber. Take a ruler and place it vertically along the first column under "NAME" and follow along until you have the man's name and address. We'll give you a tip—the first two columns say "Mr." See if you can read any other information on this card, which can be fed into a card reader and a printer to make labels, bills, lists of subscribers, etc.

Now you're ready to put your own name into Hollerith code for this requirement. If your name were Samuel John Goodscout, it would look like this: 0-2 12-1 11-4 0-4 12-5 11-3 11-1 11-6 12-8 11-5 12-7 11-6 11-6 12-4 0-2 12-3 11-6 0-4 0-3.

See if you can read this *Scouting Magazine* subscription card.



Computer Terms



5. Tell the meaning of six of the following:

a.	**memory**	**g.**	**channel**
b.	**bits**	**h.**	**interrupt**
c.	**on-line**	**i.**	**register**
d.	**bytes**	**j.**	**console**
e.	**microsecond**	**k.**	**central processing unit**
f.	**address**		

Individually, the terms listed in this requirement do not have a great deal of meaning, but grouped together their significance becomes more apparent. We choose to group the terms as follows:

i.	memory	ii.	channel
	bits		on-line system
	bytes		interrupt
	address	iii.	central processing unit
	microsecond		console
			register

The speed of a memory is measured as the time to find the information and the time to make a copy of the information. This time may be very small, in the order of one millionth of a second.

In order to ease the wordiness of referring to small portions of a second, names have been given to the fractions:

Name	Meaning	Abbreviation
millisecond	a thousandth of a second	msec
microsecond	a millionth of a second	μsec
nanosecond	a thousandth of a microsecond	nsec

Thus, when a manufacturer says that he builds a computer with a 2.5 microsecond memory, he means that the memory is able to find a piece of information in 2.5 millionths of a second.

A piece of information in a memory is only one of many thousands. To locate a single item of information in the memory, each part of the memory that can contain a single piece of information (called a *word*) is given an *address*. This is almost the same as the scheme we use in finding a house in a city. Each house

is identified by a street name and a house number—the house address. In the computer, we use very large numbers for addresses and, thus, do away with the street name. In the same way as a house address does not tell anything about who lives in the house, so also the word address of a piece of information tells nothing about the information.

The memory of a computer is usually made up of thousands of *words*. In turn, each word is composed of a set of characters (as is a word in the English language). Since a computer memory is made of electronic devices, it is capable of recording only 1's and 0's. Therefore, the makeup of a word is also a set of 1's and 0's. These individual parts of a word are known as *bits,* since they are the digits of a binary numbering system. Sets of bits within a word may be thought of as larger pieces and treated in a special manner. A collection of bits is called a *byte*. Usually, a byte is made up of eight bits, though this is not always true for all computers.

When the computer system has more than one input/output device, it is possible to program the computer to make best use of all its abilities by the simultaneous operation of the devices. Since input/output devices each work at different speeds, it is difficult for the central processing unit to keep track of what is happening at any one time. Thus, the control of input/output devices has been taken from the central processing unit, and the devices are made small computers themselves. The *channels* of the computer system make it possible for a computer to be inputing data from several devices, outputing data to several devices, and executing a program—all at the same time.

Each input device has a small memory of its own so that it can be read from the card independently of the work going on in the central processing unit. This small memory is known as a *buffer*. When the data has been read into the buffer, the input device sends a signal to the computer to *interrupt* its present work and move the data from its buffer memory to the computer memory. This move can be done at electronic speeds (memory to memory) rather than the mechanical speed of a reader (holes in a card to memory).

Similarly, on output the central processing unit can send data from its memory to the buffer memory of the output unit and then go on with more work. When the

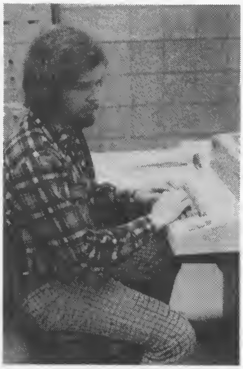
output unit has completed moving that data to paper tape, card, or printed page, an interrupt signal can be sent back to the central processing unit to say "I've finished that job; I'm ready for some more."

Where devices are told what to do by the central processing unit, they are *on-line.* If a computer system produced the answer on a set of punched cards (card deck), the programmer or user would have to take them to another machine to get a printing of the meanings of the holes in the cards. That second machine—a card interpreter—not being under the control of the central processing unit, is *off-line.* Similarly, machines used in preparation of cards for input to a computer (keypunch machines) are also off-line.

The *central processing unit* (CPU) of a computer is that unit which contains the circuits for controlling the operations of the system and especially for following instructions of a program. This unit may be thought of as the "heart" and "brain" of a computer, since without it the machine could not be classified as a true computer.

Physically, the CPU can usually be identified as the module on which all the lights and switches are mounted. These lights and switches are rarely used by the programmer but are put there by the manufacturer to assist the computer engineers and operators to diagnose faults with the machine. Like most machines, a computer can get "sick" due to a faulty wire, a bad component, or a poor power supply. This display of lights and switches together with a typewriter input/output unit make up the *console* of the computer through which the operator and the computer directly communicate with each other.

Within the CPU of a computer are *registers*—small memory units designed to contain special information for the operation of the unit. These registers contain such information as the address of the instruction to be executed next, the instruction being executed, the result of the last calculation, or the time of the day. The lights on the console usually show the data stored in these registers, and the switches enable the operator to change these values.



More Computer Terms

6. Tell the meaning and use of 12 of the following:

a. business data processing
b. information retrieval
c. simulation
d. scientific processing
e. floating point
f. truncation
g. fixed point
h. accuracy
i. input
j. record
k. output
l. file
m. software
n. instruction
o. hardware
p. indexing
q. loop
r. subroutine
s. real time
t. time sharing
u. cybernetics

As in the previous requirement, the terms listed are subdivided into related groups as follows:

i. business data processing
scientific processing
information retrieval
simulation
ii. floating point
fixed point
truncation
accuracy
iii. input
output
record
file
iv. hardware
software
instruction
indexing
loop
subroutine
v. real time
time sharing
vi. cybernetics

The term "data processing" covers all aspects of computing and is not necessarily restricted to computers as we have defined them here. Any processing operation that takes in data and produces more data as a result is a data processing operation. Within this wide classification, there exists the restricted operations of *business data processing* and *scientific processing.*

Business data processing usually concerns the use of a computer system in the accounting or management parts of a business. The use of a computer by a bank is an example. In fact, any use of a computer to help in the administration of a business, which may include highly scientific calculations (such as financial forecasting or the calculation of the best way to operate an

assembly line), is a part of business data processing.

Scientific processing is the use of a computer system to solve a problem related to understanding a natural phenomenon or the design of an engineering project. The use of computers in the space program to direct and monitor space exploration is an application of scientific processing.

Both scientists and business executives need to get information quickly and accurately. With the large libraries of books and documents available today, it is expensive for the scientist to "browse" until he finds what he wants. It is better for the computer to have this information in its memory and provide it to the scientist on demand. The computer can identify a book of interest far more quickly than a man can look through a library catalog. But even then, the scientist may not want to read the whole book but is only interested in one subject or chapter or maybe the library contains several books on the same topic and the scientist cannot afford to read all the books. The computer can summarize and integrate all the available information and give the scientist what he needs in far less time.

Similarly, the business executive needs to have at his fingertips all the current information on his company and perhaps on his competitors. This, too, could fill a whole library, but, even worse, it is changing all the time. Given to a computer storage system, the computer can provide the same kind of service to the executive as to the scientist. This service is known as *information retrieval.*

In both business and scientific operations, it is not always possible to experiment with a process to find out "what would happen if . . . ." For example, it would be very costly to find out all the possible things that could go wrong in a space shot to the moon by just launching a rocket. Thus, the scientist uses a mathematical model of a process and finds out what happens to the model when certain things (stimuli) are applied to it. This process is known as *simulation.*

Simulation is also being used in education to teach students what happens when they make a decision or do something to a process. As used in this connection, it must not be confused with the type of simulation used on national television during space shots, which is regarded more accurately as "animation."

The memory of a computer contains both the instructions of the program to be followed and the data to be used by that program. In general, the data consists of numbers which are to be used in the calculations. Since a word of memory must be designed and built before any one of the problems to be solved is known, the memory bank cannot be especially designed for each problem. It is not economical to build a memory bank in which the size of each word is different, and so the designers make the number of bits in each word of the memory the same. However, the number of digits in each piece of data used is not necessarily the same. Within the computer, numbers are either "filled out" (by adding 0's) or "truncated" (literally, cut off) to fit the word size of the memory. Filling out with 0's doesn't make any difference, but the need to truncate can cause serious problems.

The process of *truncation* is designed so that the most important digits in a number are saved for calculation. For example, we know the distance from the center of Times Square in New York to the Washington Monument in Washington, D. C., to within a fraction of an inch. Yet, if you were to drive from Times Square to the Washington Monument, it would be sufficient to know the distance only to the nearest mile and the time taken to the nearest minute to work out your average speed with an accuracy with which you would be satisfied. Do you really care whether your average speed was 47 mph or 47.32841 mph?

The *accuracy* with which a measurement is given, such as the average speed of your car, is the freedom from error of that measurement. Accuracy has nothing to do with the number of digits with which a measurement is stated. Conversely, the *precision* of a measurement is the degree of accuracy.

With respect to a word in a computer memory, the number of bits available to represent a number is a measure of the precision of the computer. The accuracy of a computer is measured by the result of a calculation, which in turn may be affected by the truncation necessary to fit the result back into a word of the memory for storage and later reference.

Since the number of bits in a word of the computer's memory is fixed, the set of numbers which it is possible to represent is also fixed. Further, since the memory of a computer is made up of only 1's and 0's, it is not

possible to have a number which contains either a sign (plus or minus) or a radix point. To overcome this problem, one bit of each word has been set aside to mean the sign of a number. When this particular bit is 0, the number is positive. When the bit is 1, the number is considered negative or less than 0.

The problem of knowing where the radix point is located is solved by one of two methods. In a *fixed point* representation, the radix point is assumed to be either at the left-hand end or the right-hand end of the number, depending on the particular machine. In a *floating point* representation, the word of the memory is divided into two parts, the *exponent* and the *mantissa*. The mantissa is a fixed-point number, usually a proper fraction, and the exponent is an integer indicating how many places the radix should be moved to put it into its proper position. The exponent also has a special bit indicating whether the radix point should be moved left or right.

The organization of data for the purposes of *input* or *output* into "blocks" or groups is a system which speeds up operations even more. If the work of the central processing unit had to be interrupted every time enough information had been read by the input unit to fill one word of the memory, the efficiency of the system would be reduced. For this reason, the collection of data into blocks — called *records* — and the ability to store a complete block of data in the input buffer memory before interrupting the central processing unit allow the system to operate more efficiently. Similarly on output, if the central processing unit can fill the output unit's buffer with a complete record at its own speed, rather than just one word of data, the central processing unit can go back to performing many more calculations than would be possible if it had to be interrupted every time the output unit was ready to output one more word of data.

When records are put into a magnetic tape or a disk or are prepared for input on such devices, the collection of records is a *file*. In terms of collective nouns, a collection of *words* is a *record* and a collection of *records* is a *file*.

Physically, a complete computer system may be composed of many modules, including the central processing unit; channels to facilitate communication with the input/output devices; the input/output devices

themselves; and a structured storage system. However, in order to operate such a computer system, it is also necessary to have a program or set of programs to instruct the system what to do. The physical parts of a computer system are its *hardware,* and the programs that direct the system are the *software.*

A program is made up of a set of individual machine *instructions*. These instructions are the detailed steps to be taken to solve a particular problem. The different types of instructions (such as ADD, DIVIDE, etc.) are limited to a small number in each machine; that is, the number of different possible actions that can be done by a machine is fixed by the manufacturer, and it is the programmer's job to use this small set of instructions to make a program that will solve a complex problem. Large computers may have as many as 100 different instructions.

When the program is to work on data that is organized by the programmer as a table or list, it is often necessary for the computer to work with entries in the table or list in turn. For example, you may have been given a homework problem which said "Answer the following set of questions." You would complete your assignment by answering each question in turn. The processing to select each element of a set, table, or list in order is *indexing*. Some computers provide special registers (index registers) in the central processing unit which help a programmer keep track of which element of a table or list the program is to work on next.

As where you were asked to answer a set of questions in an assignment—each really the same problem with different values—often a program must be written to solve the same problem over and over again with differing sets of data. In fact, this is what the computer is very good at doing. If you are given 20 problems to solve, you might be very good on the first few, but then you start getting tired and bored and make mistakes. The more mistakes you make, the worse it gets. The computer never gets tired or bored (it doesn't know any better) and, thus, is very good at doing the same problem over and over again.

If the programmer had to write a program for every time the problem was to be solved, he might as well solve the problem himself, since it takes as long (often longer) to write a program as it does to solve the problem. Only when the same program can be used many

times does the computer pay for itself. Some problems are solved by doing the same work over and over again (called *iteration*) until a complete solution is achieved. A computer program which is written so that one group of instructions is used over and over again to solve the same problem with different data is in a controlled *loop.*

It would be a tremendous waste of time and effort if every time a program was written it was used once and then thrown away. So programs are stored on drums, disks, or tape for use on another day. If a program has already been written to solve a problem, it would be unfortunate if it were not available to everybody who had the same type of problem to solve. Thus, libraries are developed on drums, disks, or tape from which programmers can borrow programs. In many cases, a programmer will write a program and include another program from the library. In this case he will borrow the program in the library by copying it into his larger program. This borrowed program is known as a *subprogram* or *subroutine.* Most libraries have subroutines available for calculating trigonometric functions (sine, cosine, tangent), square roots, logarithms, sorting a list of numbers, and many other jobs.

Computers are used mainly to solve problems that have no direct effect on what is happening at the time the calculations are being performed. They are also being used to control processes, such as the rolling of steel in a mill or the manufacture of paper or the production of chemicals, which require that calculations be done as the processes go on. This is *real time* processing. In many cases, computers not only control a process but also monitor the result and then predict what will happen in the future if the current trends continue. In a chemical plant, for example, a computer can direct and control the operations of the plant and also take emergency actions to prevent accidents. A man doing the same job could not recognize a problem nor react fast enough.

Computers used in the space program operate in *real time.* To operate in this mode it is necessary for the computer to perform calculations at such a speed that it predicts what will happen well before it does. If the computer were too slow, it would be useless.

Operating in *real time,* however, is not always fast enough. Astronomers have been trying to find what

happens when a star explodes. They know how to perform the calculations, but unfortunately our computers are too slow to solve the problem. If they started today, astronomers would have the answer several thousand years from now, just about the same time that the effects of a star exploding today would affect earth.

Another aspect of real time processing, though not as critical, is *time sharing*. A computer is said to be *time sharing* if it is able to divide its resources (input/output units, storage, and arithmetic abilities) between several users at the same time. With the ability of a computer system to perform input/output jobs at the same time that the central processing unit is doing calculations, a scheme was developed so that while one program is doing input or output another can be executed. In fact, since input/output is slow compared to the speed of the central processing unit, it is possible to solve many other problems while one program is waiting for input/output. Combining this scheme with the ability of the computer to converse by a telephone system, many programmers are served at once, and the efficiency of the computer is improved by using all its facilities all the time. Such systems are now available in most universities and many schools, as well as in most banks.

Time-sharing computer systems can be considered *real time* systems since they provide service on demand, but, since the timing of the response to such a demand is not critical (usually in the order of 1 second) and no process is *on-line* which must be monitored continually, the term *real time* is reserved for *time critical systems.*

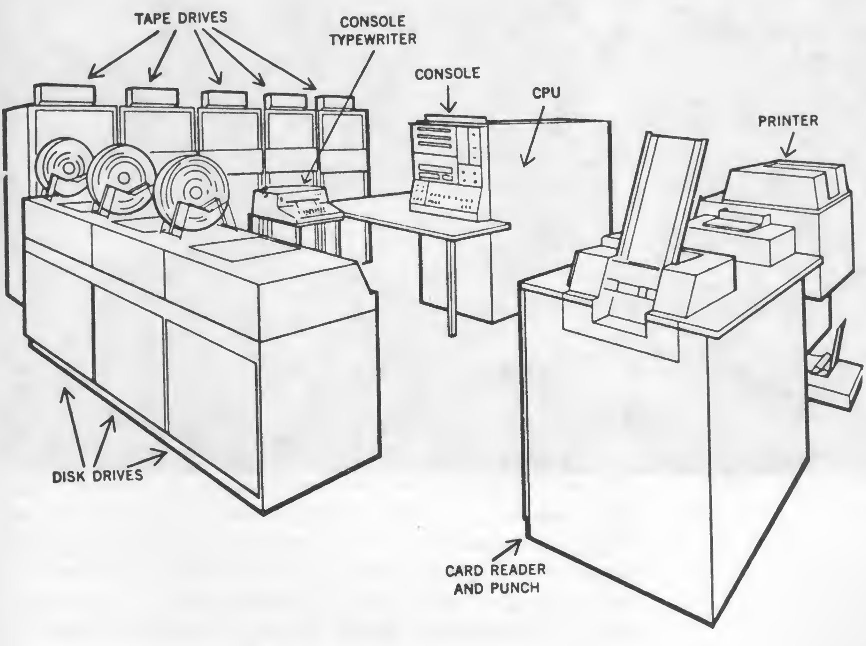
The science of *cybernetics* could be the subject of another merit badge. Cybernetics is a whole field of science which is concerned with the theories and experiments on the means of communication and control of machines and living organisms. This science is partly mathematics, partly psychology, partly neurophysics, partly electronics, and partly medical science. The term cybernetics was coined in 1947 by Norbert Weiner, a professor at the Massachusetts Institute of Technology. It is a science that is only now being researched deeply and is the subject of much science fiction. The ideas of man-made robots and androids, the control of man's brain, and the building of man-made brains are all extensions of the basic ideas of cybernetics.

Computer Installations

7. Visit a computer installation. Study how it works.

Since there are now many thousands of computers in this country, it should not be difficult to find a computer installation within driving distance of your home. Before you go, find out what kind of work it does. Is it business data processing or scientific processing? What kind of machine is it and who is the manufacturer? If possible, call the local office of the manufacturer of the machine and ask if he has a pamphlet about the machine which he could send you.

A visit to a computer installation can be unrewarding unless you are prepared to ask questions. Don't be frightened that you might ask a silly question. If possible, follow the steps in which a programmer sets up a job. Start off by meeting with a programmer and see



where he works. Find out what language he uses to communicate with the computer. Ask if you can see a copy of a program. Find out how the program written by the programmer is converted into a form to be read by the computer. Does the computer use cards or magnetic tape? Follow the program through the input/output room to the computer. Be there when the program is run and see the output being produced by the computer.

Get a plan of the computer room, if possible, and mark on it where each component of the computer is placed. Find out how much air conditioning is used, how much electrical power is needed to run the computer, how many people work for the center, who uses it, how much it costs to operate per hour, and lots of other questions that you should be able to think of yourself.

Careers in the Computer Field

8. Do the following:

a. Explain what each of the following does:

design engineer	**analyst**
customer engineer	**operator**
programmer	**salesman**

b. Read two pieces of information about computers. Describe what you read.

c. Describe jobs in the computer field.

Initially, the *computer salesman* for a computer manufacturer (who probably already has a number of models of computers on the market) contacts his clients to find out what their future needs are likely to be. The client states what he thinks his institute or company will be doing in the years to come.

From those projections, the salesman tells his *design engineer* what he needs a computer to do. At the same time, the design engineer has been following the research being done by his company and knows what new products might be ready. By putting together the needs of the client with the abilities of the manufacturer, the design engineer begins the design of a new computer system. Once he has a rough idea what the new computer will look like, he simulates the new machine on an existing computer to find out if the design really works.

At the same time, *customer engineers,* who are the local representatives of the computer manufacturer and install and maintain the computer at the customer's installation, are trained and readied for the first deliveries. Unlike a car or a toaster, a computer cannot be sent back to the factory for repairs and, thus, the *customer engineer* must travel to the installation. Also, each order for a computer system will probably be different from each other machine delivered, because differing amounts of memory and input/output devices are ordered to suit the exact needs of the client. Since computers are very expensive, each client will only take as much equipment as he needs. Fortunately, most computers are built so that additional units can be added later as needed.

Before the computer is delivered to the client, the *computer operators* (people who will operate the computer) have to be trained. Most manufacturers run training schools at their plants or offices. Smaller machines can be operated by relatively inexperienced people after only a day of training, but the operation of larger machines may require several weeks of education.

Since each model of a computer is designed individually, the machine language of the computer will not necessarily be the same as that of any other model, though the higher level languages are expected to be the same on all machines. Thus, the *programmers* of the installation must also start training before the machine is installed. In this way, by the time the machine is ready to start operations, the operators have been trained to operate it and the programmers have the knowledge on how to write programs for it. No time is wasted.

During this time the programmers in the plant of the computer manufacturer have been developing software for the system to translate higher level languages, to control a time-sharing system, and to supervise the general operation of the system. Without these programs it would be difficult for the programmers of the customer to efficiently use the machine.

Like the computer hardware, the software of the computer system needs to be maintained during its use. Often the manufacturer finds better ways of doing things that will help the programmers, or he may find that the software contains some errors. It is difficult to return software to the factory for repair, and so a *systems engineer* works with the customer to service the software.

A person with a problem in a company which took delivery of the computer, who is not a programmer himself, will go to the computing center for help. Initially, he meets with an *analyst* who will determine what the problem is and whether it is suitable for solution by the computer. If he decides that the problem is to be solved by using the computer, the analyst will work with the person to find out in detail how the problem is to be solved and what information will be needed to produce a solution. When all this information is gathered, the analyst and this person meet with the programmer whose job it will be to translate the

statement of the problem as developed by the analyst into a program. Once this is done, a test solution is run to find out if the program works as expected and that no errors have been made either in stating the problem or in writing a program for its solution. Finally, when the program is running properly the programmer and the analyst write a report and hand the program over to the person with the problem for his use.

We have discussed the types of jobs that are available both in a manufacturer's plant or office and in the installation center of a customer. Other opportunities include keypunch operators, clerical staff, receptionists, report writers, and many others associated with business. Take the opportunity when you visit a computer installation to ask about careers in this industry. Ask what educational requirements are needed for each job.

From your nearest state or private college or university find out what courses can be taken that will prepare you for a career in this field. Then find out what courses you will need in high school to satisfy the requirements of college entrance.

Books About Computers Merit Badge

De Rossi Claude. *Computers: Tools for Today*. Children's Press, 1972.

Includes the history of computers and how they work. Especially good for boys interested in a career in the field.

Meadow, Charles T. *The Story of Computers*. Harvey House, 1970.

Explains simply how computers work and how they are programmed. Excellent diagrams and drawings. Useful chapters on computer use in space travel and weather prediction.

Srivastava, Jane. *Computers*. Crowell, 1972. (A Young Math Book)

A very simple first book introducing the reader to the terminology of data processing.

Vorwald, Allan. *Computers! From Sand Table to Electronic Brain*. 3d edition. McGraw-Hill, 1970.

Good coverage on all aspects. Includes instructions for those who would like to build their own computers.

"Facts on Computer Careers" and "The Quiet Revolution: Computers Come of Age" are available from American Federation of Information Processing Societies, Inc., 210 Summit Ave., Montvale, N.J. 07645.

Much of the periodical literature about computers is very technical and requires considerable knowledge of electronics. However, the Data Processing Management Association, 524 Busse Highway, Park Ridge, Ill. 60068 can furnish supplemental reading of nontechnical material about computers, mainly data-processing systems.

Several periodicals cover the computing field from the point of view of personal computing and "do-it-yourself" machine design. See *Creative Computing*, published bimonthly by Creative Computing, P.O. Box 789-M, Morristown, N.J. 07960.

NOTES

NOTES

MERIT BADGE LIBRARY

Though intended as an aid to Boy Scouts and Explorers in meeting merit badge requirements, these pamphlets are of general interest and are made available by many schools and public libraries. The latest revision date of each, which may not necessarily correspond to the copyright date of the pamphlet, is shown below (corrected to June 1, 1981).

Number		Year
3325	American Business	1975
3388	American Cultures	1980
3398	American Heritage	1976
3395	Animal Science	1975
3381	Archery	1978
3321	Architecture	1966
3320	Art	1968
3303	Astronomy	1971
3324	Athletics	1964
3275	Atomic Energy	1965
3293	Aviation	1968
3313	Basketry	1968
3362	Beekeeping	1975
3282	Bird Study	1967
3378	Bookbinding	1969
3379	Botany	1964
	Bugling (see Music)	
3256	Camping	1966
3308	Canoeing	1980
3367	Chemistry	1973
3253	Citizenship in the Community	1972
3252	Citizenship in the Nation	1972
3254	Citizenship in the World	1972
3390	Coin Collecting	1975
3258	Communications	1976
3338	Computers	1973
3387	Consumer Buying	1975
3257	Cooking	1967
3277	Cycling	1971
3394	Dentistry	1975
3289	Dog Care	1972
3273	Drafting	1965
3206	Electricity	1974
3279	Electronics	1977
3366	Emergency Preparedness	1974
3335	Energy	1978
3376	Engineering	1978
3363	Environmental Science	1972
3346	Farm Mechanics	1958
3348	Farm and Ranch Management	1980
3287	Fingerprinting	1964
3317	Firemanship	1968
3276	First Aid	1981
3307	Fish and Wildlife Management	1972
3295	Fishing	1974
3399	Food System	1978
3302	Forestry	1971
3240	Gardening	1976
3383	Genealogy	1973
3332	General Science	1972
3284	Geology	1953
3397	Golf	1977
3370	Handicapped Awareness	1981
3380	Hiking	1962
3329	Home Repairs	1961
3298	Horsemanship	1974
3358	Indian Lore	1959
3353	Insect Life	1973
3350	Journalism	1976
3355	Landscape Architecture	1969
3389	Law	1975
3310	Leatherwork	1970
3278	Lifesaving	1980
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